COVID in MA analyzer

Introduction and citations

Data sources

I'm using the wiki compilation at https://en.wikipedia.org/wiki/2020_coronavirus_pandemic_in_Massachusetts which gives confirmed cases of COVID-19 in Masachusetts, acording ultimately to the daily updates from the MA Dept of Public Health, such as https://www.mass.gov/doc/covid-19-cases-in-massachusetts-as-of-march-28-2020/download .

Subsidiary factoids:

Population of Boston:

```
pop_yr=[2010, 2017];
pop_pp=[620702,685094];
pop_2020_bos=diff(pop_pp)/diff(pop_yr)*3+pop_pp(2)
```

```
pop_2020_bos = 7.1269e+05
```

Population of Massachusetts:

```
pop_yr=[2005, 2018];
pop_pp=[6.454e6,6.902e6];
pop_2020_ma=diff(pop_pp)/diff(pop_yr)*2+pop_pp(2)
```

```
pop_2020_ma = 6.9709e+06
```

Intent

Just to have an idea of when we should see a peak.

Data sets and structure

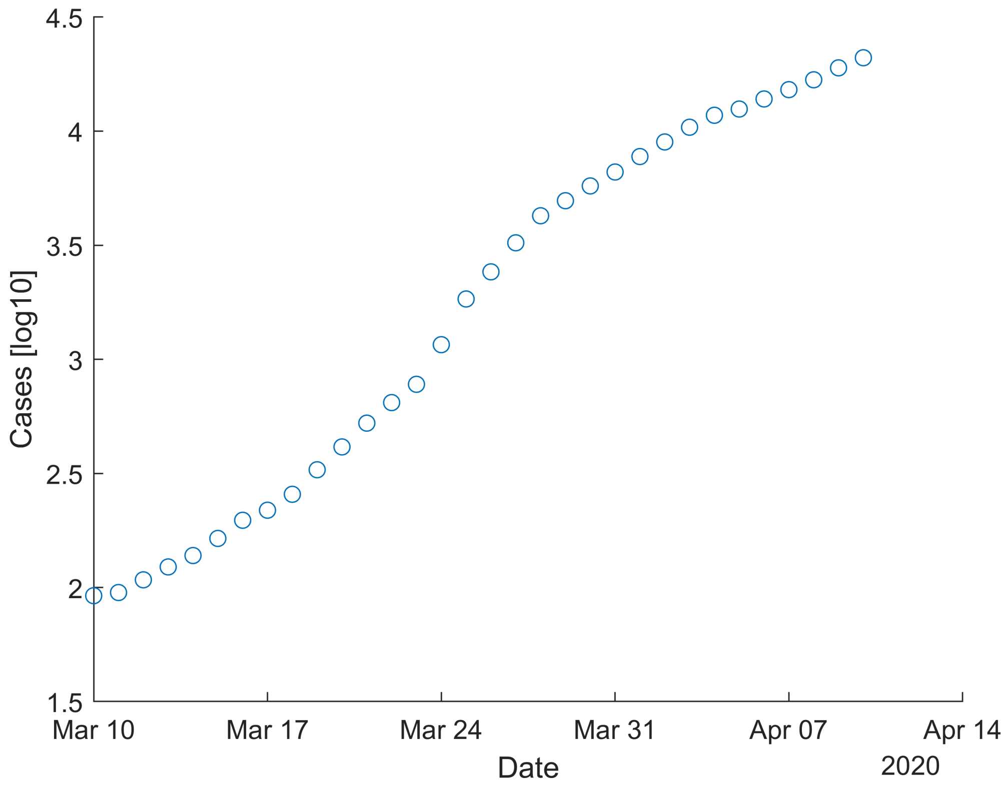
Data are given in the table Cov_Ma.

```
Cov_Ma.Properties.VariableNames
```

```
ans = 1×12 cell array
    {'Days_since_Mar_10'}    {'Cases'}    {'Date'}    {'Cases_change'}    {'Cases_growth'}    {'Tests'}    {'Tests_
```

Just the facts, ma'am

```
figure
scatter(Cov_Ma.Date, log10(Cov_Ma.Cases))
ylabel('Cases [log10]')
xlabel('Date')
```



Fitting the data to a logistic curve

The logistic curve is given by

$$m_i = \frac{k_i}{1 + e^{-(t-t_0)\cdot\gamma}}$$

where m_i is a measure of COVID (I use identified cases and identified deaths), t is th enumber of days since March 10 (a reasonble measure of when community spreading started), t_0 is the midpoint of the growth (measured in days since March 10), and γ is a constant related to growth rate.

One must initialize the vector of constants with initial conditions to begin the minimization that finds the best-fitting array of constants.These are determined by trial and error. Good practice is to use a variety of IC to make sure the solution i srobust. The ICs are in array $beta0_i$. MATLAB makes fitting the model pretty easy.

FIts

Cases

```
modelfun_c = @(b,x)b(1)./(1+exp(-(x-b(2))*b(3)))
```

```
modelfun_c = function_handle with value:
    @(b,x)b(1)./(1+exp(-(x-b(2))*b(3)))
```

```
beta0_c = [40000 50 0.05];
```

```
mdl_c = fitnlm(Cov_Ma.Days_since_Mar_10,Cov_Ma.Cases,modelfun_c,beta0_c)
```

```
mdl_c = 
Nonlinear regression model:
    y ~ F(b,x)

Estimated Coefficients:
          Estimate       SE        tStat       pValue  
          ________    ________    ______    __________

    b1      28515       1807.4    15.777    9.0713e-16
    b2     26.893       0.6596    40.772    3.6793e-27
    b3    0.21206     0.010027    21.149    3.5941e-19


Number of observations: 32, Error degrees of freedom: 29
Root Mean Squared Error: 412
R-Squared: 0.996,  Adjusted R-Squared 0.996
F-statistic vs. zero model: 4.28e+03, p-value = 1.81e-38
```

Deaths

```
modelfun_d = @(b,x)b(1)./(1+exp(-(x-b(2))*b(3)))
```

```
modelfun_d = function_handle with value:
    @(b,x)b(1)./(1+exp(-(x-b(2))*b(3)))
```

```
beta0_d = [100 20 0.222];
mdl_d = fitnlm(Cov_Ma.Days_since_Mar_10,Cov_Ma.Deaths,modelfun_d,beta0_d)
```

```
mdl_d = 
Nonlinear regression model:
    y ~ F(b,x)

Estimated Coefficients:
          Estimate       SE        tStat       pValue  
          ________    ________    ______    __________

    b1     2023.3       670.27    3.0187     0.0052485
    b2     34.948       2.2819    15.315    1.9615e-15
    b3    0.22211     0.013955    15.916    7.2063e-16


Number of observations: 32, Error degrees of freedom: 29
Root Mean Squared Error: 11.7
R-Squared: 0.995,  Adjusted R-Squared 0.995
F-statistic vs. zero model: 2.86e+03, p-value = 6.12e-36
```

Predictions

```
Pred_window=21;
Pred_days=0:max(Cov_Ma.Days_since_Mar_10)+Pred_window;
Pred_dates=(min(Cov_Ma.Date):days(1):max(Cov_Ma.Date)+days(Pred_window))';
[Cov_Ma_Pred.cases, Cov_Ma_Pred.casesci]=predict(mdl_c,Pred_days','Prediction','observation');
[Cov_Ma_Pred.deaths, Cov_Ma_Pred.deathsci]=predict(mdl_d,Pred_days','Prediction','observation'
```

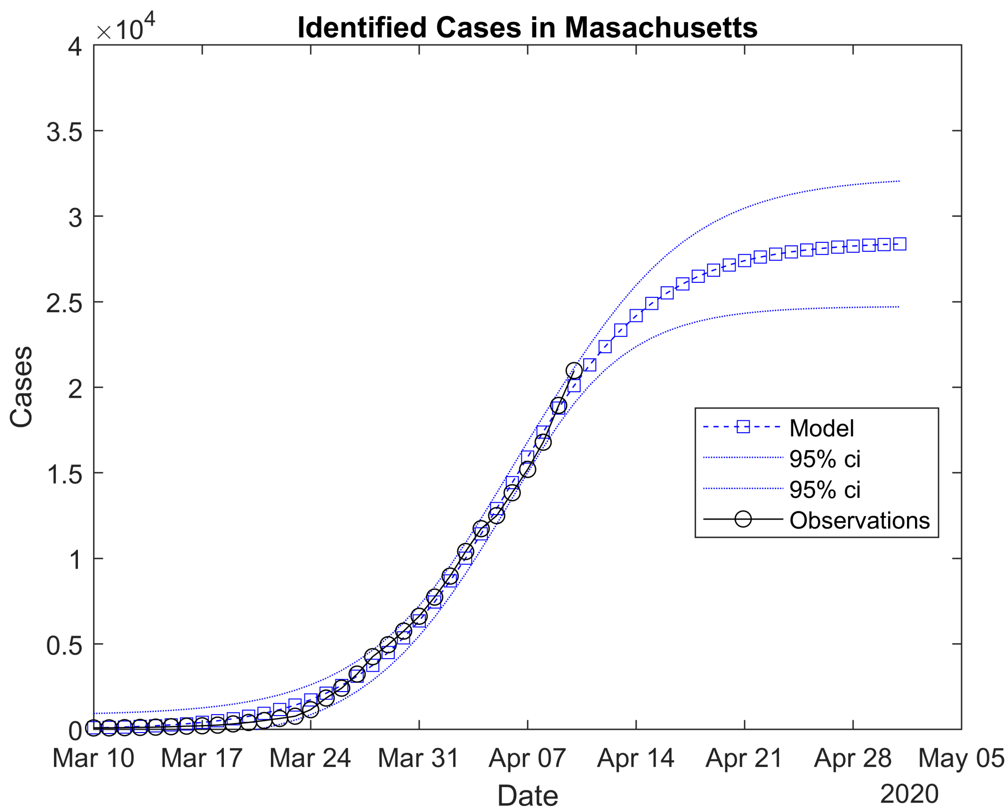
Graph the data and the models up

Cases

```
figure
plot(Pred_dates,Cov_Ma_Pred.cases,'--bs')
hold
```

```
Current plot held
```

```
plot(Pred_dates,Cov_Ma_Pred.casesci(:,1),':b')
plot(Pred_dates,Cov_Ma_Pred.casesci(:,2),':b')
plot(Cov_Ma.Date,Cov_Ma.Cases, '-ko')
ylabel('Cases')
xlabel('Date')
ylim([0,40000])
title('Identified Cases in Masachusetts')
legend('Model','95% ci','95% ci','Observations', 'location', 'best')
```

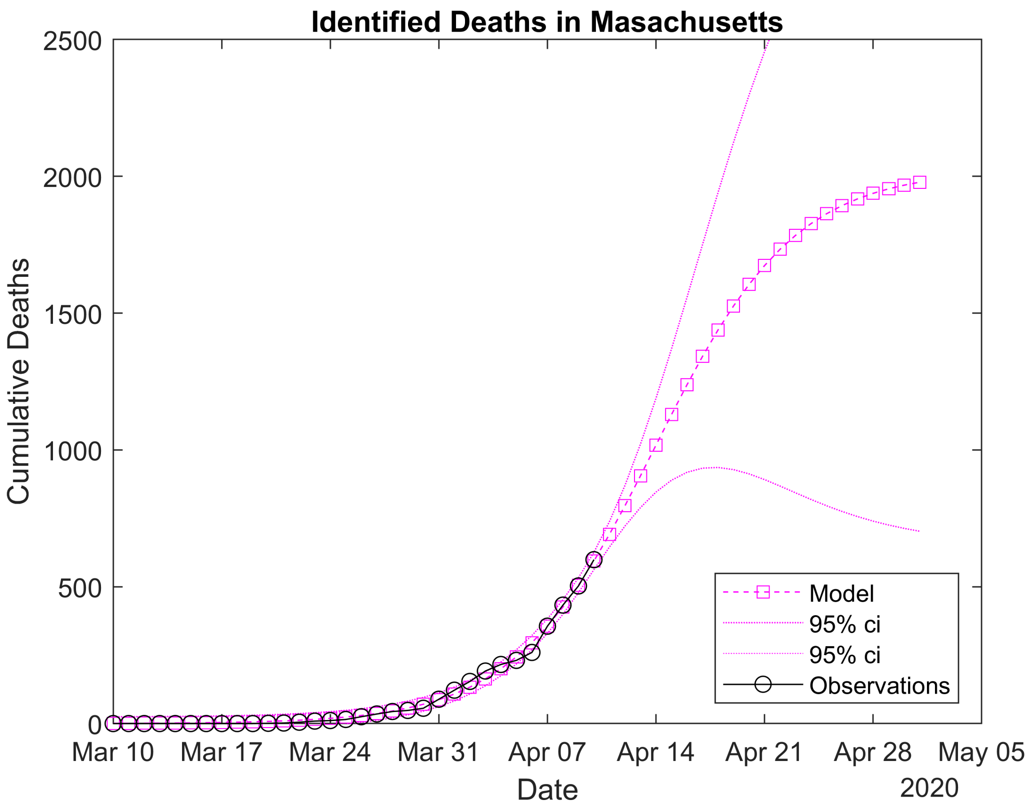


Deaths

```
figure
plot(Pred_dates,Cov_Ma_Pred.deaths,'--ms')
hold
```

```
Current plot held
```

```
plot(Pred_dates,Cov_Ma_Pred.deathsci(:,1),':m')
plot(Pred_dates,Cov_Ma_Pred.deathsci(:,2),':m')
plot(Cov_Ma.Date,Cov_Ma.Deaths,'-ko')
ylabel('Cumulative Deaths')
xlabel('Date')
ylim([0,2500])
title('Identified Deaths in Masachusetts')
legend('Model','95% ci','95% ci','Observations', 'location', 'best')
```



When are the peaks?

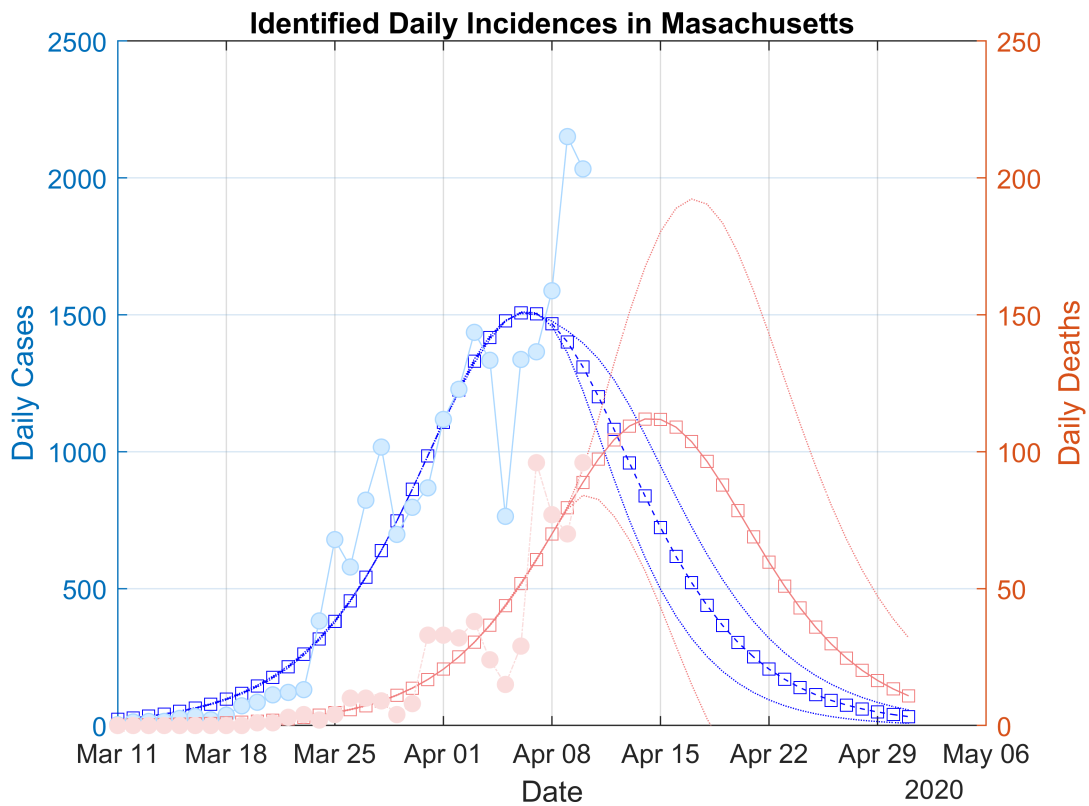
Take the differences in the cumulative graphs and plot them up to see the peaks.

```
figure
yyaxis right
plot(Pred_dates(2:end),diff(Cov_Ma_Pred.deaths),'Color', [.94 .5 .5], 'LineStyle','-', 'Marker
hold
```

```
Current plot held
```

```
grid
plot(Pred_dates(2:end),diff(Cov_Ma_Pred.deathsci(:,1)),'Color', [.94 .5 .5], 'LineStyle',':')
plot(Pred_dates(2:end),diff(Cov_Ma_Pred.deathsci(:,2)),'Color', [.94 .5 .5], 'LineStyle',':')
plot(Cov_Ma.Date(2:end),diff(Cov_Ma.Deaths),'Color', [.98 .88 .88], 'MarkerFaceColor',[.98 .88
ylabel('Daily Deaths')
xlabel('Date')
```

```
ylim([0,250])
title('Identified Daily Incidences in Masachusetts')
%legend('Model','95% ci','95% ci','Observations', 'location', 'best')
yyaxis left
plot(Pred_dates(2:end),diff(Cov_Ma_Pred.cases),'--bs')
plot(Pred_dates(2:end),diff(Cov_Ma_Pred.casesci(:,1)),':b')
plot(Pred_dates(2:end),diff(Cov_Ma_Pred.casesci(:,2)),':b')
plot(Cov_Ma.Date(2:end),diff(Cov_Ma.Cases),'Color', [.68 .85 1], 'MarkerFaceColor', [.84 .92 1
ylabel('Daily Cases')
```




```
%xlabel('Date')
%ylim([0,50])
%title('Identified Daily Incidences in Masachusetts')
%legend('Model','95% ci','95% ci','Observations', 'location', 'best')
```

Using previous results to predict the short-term future

Cases

```
modelfun_c = @(b,x)b(1)./(1+exp(-(x-b(2))*b(3)))
```

```
modelfun_c = function_handle with value:
    @(b,x)b(1)./(1+exp(-(x-b(2))*b(3)))
```

```
for indx=15:Cov_Ma.Days_since_Mar_10(end)
    beta0_c = [18000 25 0.24];
    mdl_c = fitnlm(Cov_Ma.Days_since_Mar_10(1:indx),Cov_Ma.Cases(1:indx),modelfun_c,beta0_c);
```

```
end
```

```
Warning: Iteration limit exceeded. Returning results from final iteration.
Warning: The Jacobian at the solution is ill-conditioned, and some model parameters may not be estimated
well (they are not identifiable). Use caution in making predictions.
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Warning: Iteration limit exceeded. Returning results from final iteration.
Warning: The Jacobian at the solution is ill-conditioned, and some model parameters may not be estimated
well (they are not identifiable). Use caution in making predictions.
```

Deaths

```
modelfun_d = @(b,x)b(1)./(1+exp(-(x-b(2))*b(3)))
```

```
modelfun_d = function_handle with value:
    @(b,x)b(1)./(1+exp(-(x-b(2))*b(3)))
```

```
beta0_d = [5000 40 0.222];
mdl_d = fitnlm(Cov_Ma.Days_since_Mar_10,Cov_Ma.Deaths,modelfun_d,beta0_d)
```

```
mdl_d = 
Nonlinear regression model:
    y ~ F(b,x)

Estimated Coefficients:
          Estimate       SE        tStat       pValue  
          ________    ________    ______    __________

    b1     2023.3       670.46    3.0178     0.0052601
    b2     34.947       2.2822    15.313    1.9692e-15
    b3    0.22211     0.013954    15.917    7.2019e-16


Number of observations: 32, Error degrees of freedom: 29
Root Mean Squared Error: 11.7
R-Squared: 0.995,  Adjusted R-Squared 0.995
F-statistic vs. zero model: 2.86e+03, p-value = 6.12e-36
```